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(54) **Air conditioning controller display**

(57) A microprocessor based controller 1 for use in air conditioning systems is capable of controlling two separate control loops and has for each loop at least one input for receiving external values and at least one output for delivering control values. First display means 2 are provided for displaying the value or state of a selected parameter of one or other of the loops, the selected parameter being identified by the illumination of a corresponding discrete display element adjacent an associated defining legend, the elements and legends being arranged in a list 9 forming a second display. Selector keys 14, 15 are provided for selecting from the list parameter to be displayed. Two further keys 6, 7 are provided for adjusting the value or state of a currently displayed adjustable value. The microprocessor (20) performs an auto-configuration routine upon power-up or interrupt to determine, from the inputs connected, which parameters may be selected.

Self testing routines may be selected by the user to test the elements of the controller, such as the display, the keyboard etc, to assist in fault diagnosis or in commissioning.

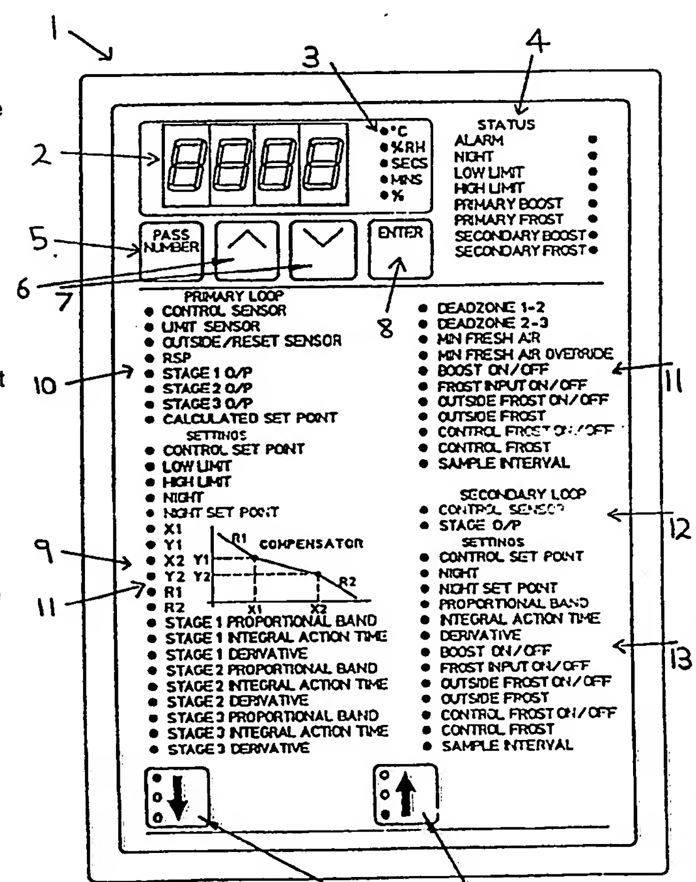


FIGURE 1

GB 2 256 940 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

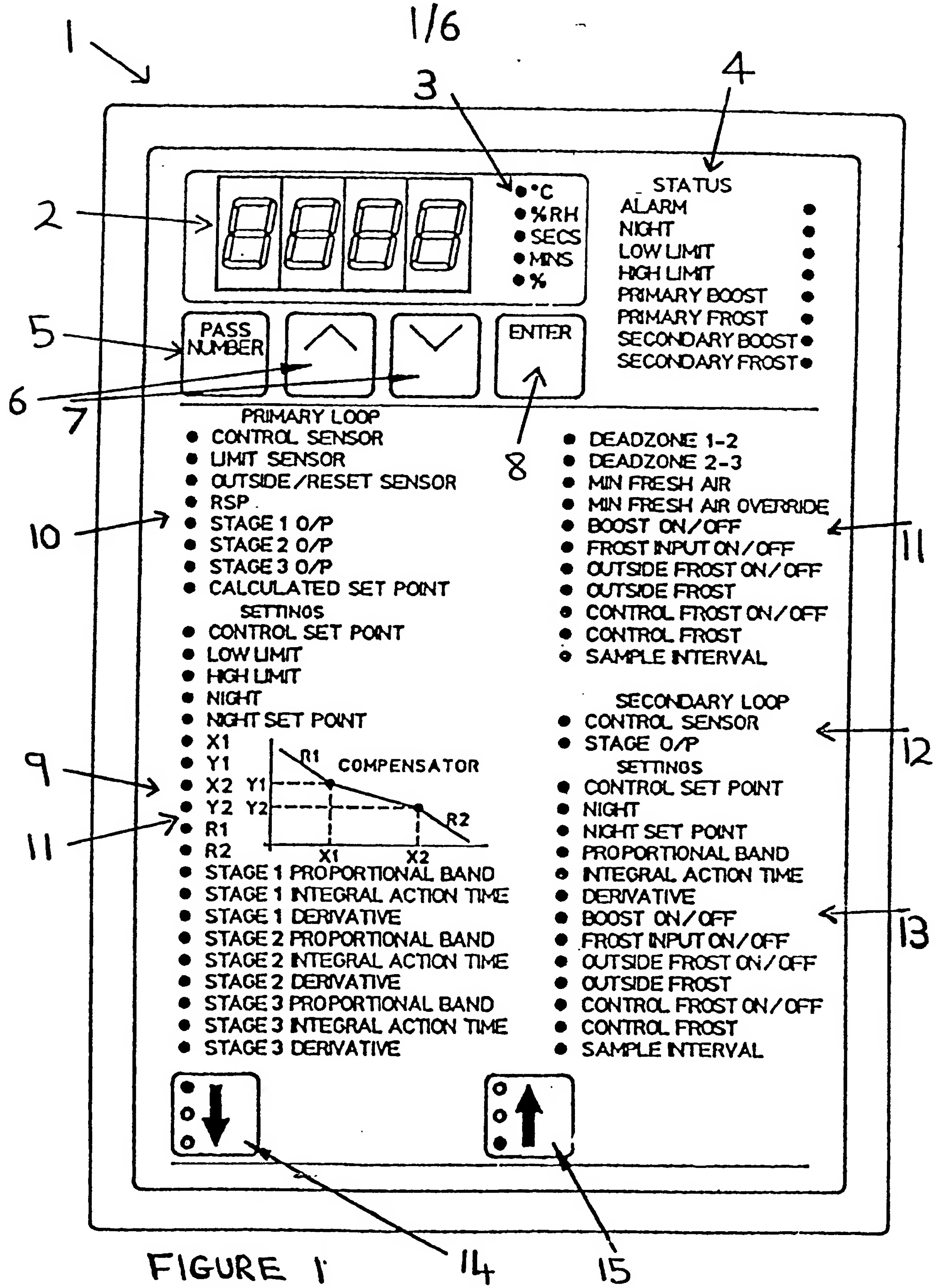
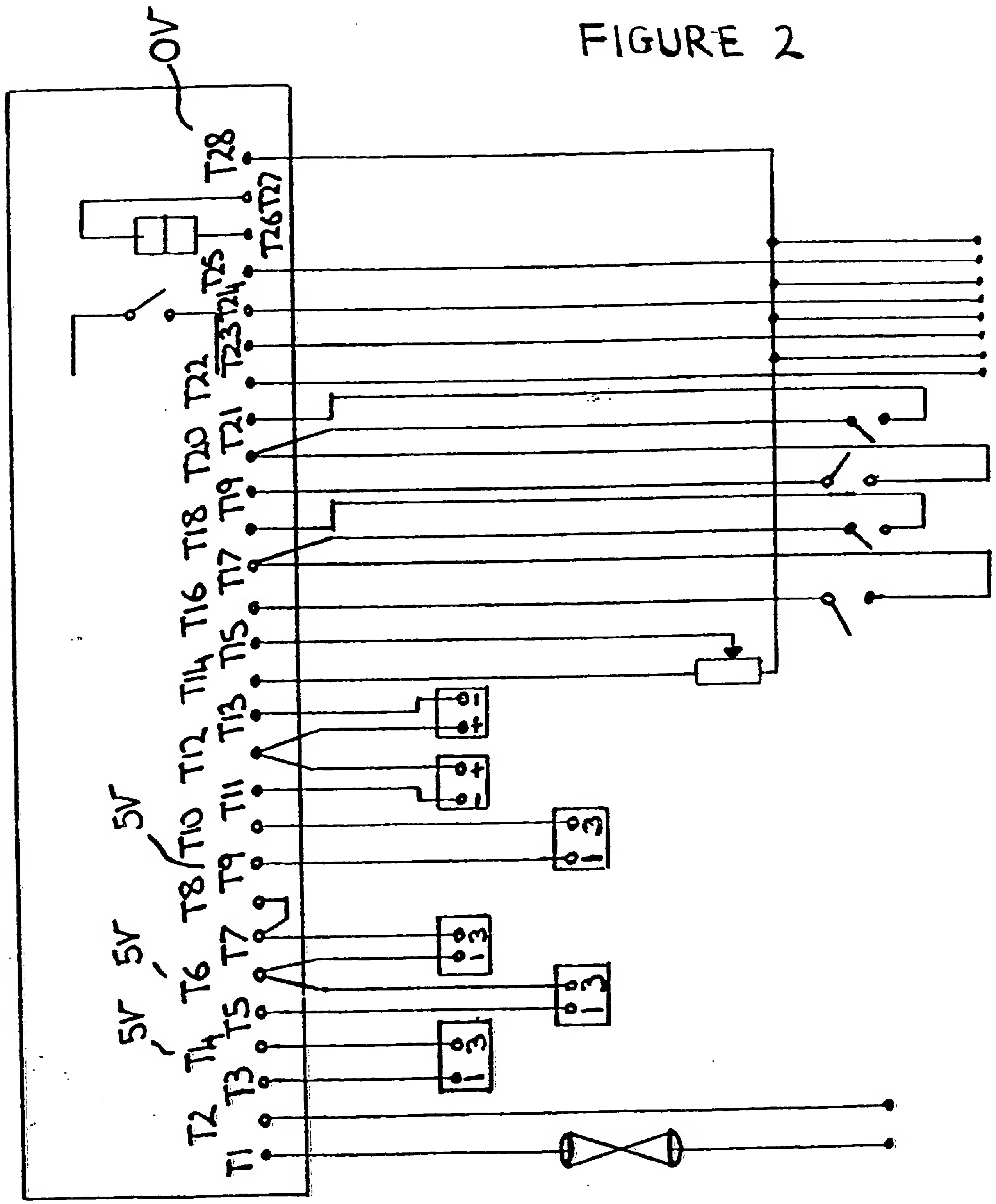

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
°C
%RH
SECS
MINS
%
STATUS
ALARM
NIGHT
LOW LIMIT
HIGH LIMIT
PRIMARY BOOST
PRIMARY FROST
SECONDARY BOOST
SECONDARY FROST
PASS NUMBER
ENTER
PRIMARY LOOP
CONTROL SENSOR
LIMIT SENSOR
OUTSIDE/RESET SENSOR
RSP
STAGE 1 O/P
STAGE 2 O/P
STAGE 3 O/P
CALCULATED SET POINT
SETTINGS
CONTROL SET POINT
LOW LIMIT
HIGH LIMIT
NIGHT
NIGHT SET POINT
X1
Y1
X2
Y2
R1
R2
COMPENSATOR
STAGE 1 PROPORTIONAL BAND
STAGE 1 INTEGRAL ACTION TIME
STAGE 1 DERIVATIVE
STAGE 2 PROPORTIONAL BAND
STAGE 2 INTEGRAL ACTION TIME
STAGE 2 DERIVATIVE
STAGE 3 PROPORTIONAL BAND
STAGE 3 INTEGRAL ACTION TIME
STAGE 3 DERIVATIVE
DEADZONE 1-2
DEADZONE 2-3
MIN FRESH AIR
MIN FRESH AIR OVERRIDE
BOOST ON/OFF
FROST INPUT ON/OFF
OUTSIDE FROST ON/OFF
OUTSIDE FROST
CONTROL FROST ON/OFF
CONTROL FROST
SAMPLE INTERVAL
SECONDARY LOOP
CONTROL SENSOR
STAGE O/P
SETTINGS
CONTROL SET POINT
NIGHT
NIGHT SET POINT
PROPORTIONAL BAND
INTEGRAL ACTION TIME
DERIVATIVE
BOOST ON/OFF
FROST INPUT ON/OFF
OUTSIDE FROST ON/OFF
OUTSIDE FROST
CONTROL FROST ON/OFF
CONTROL FROST
SAMPLE INTERVAL

FIGURE 1

FIGURE 2


0V
T28
T26
T27
T25
T24
T23
T22
T21
T20
T19
T18
T17
T16
T15
T14
T13
T12
T11
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5V
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T5
T4
T3
T2
T1

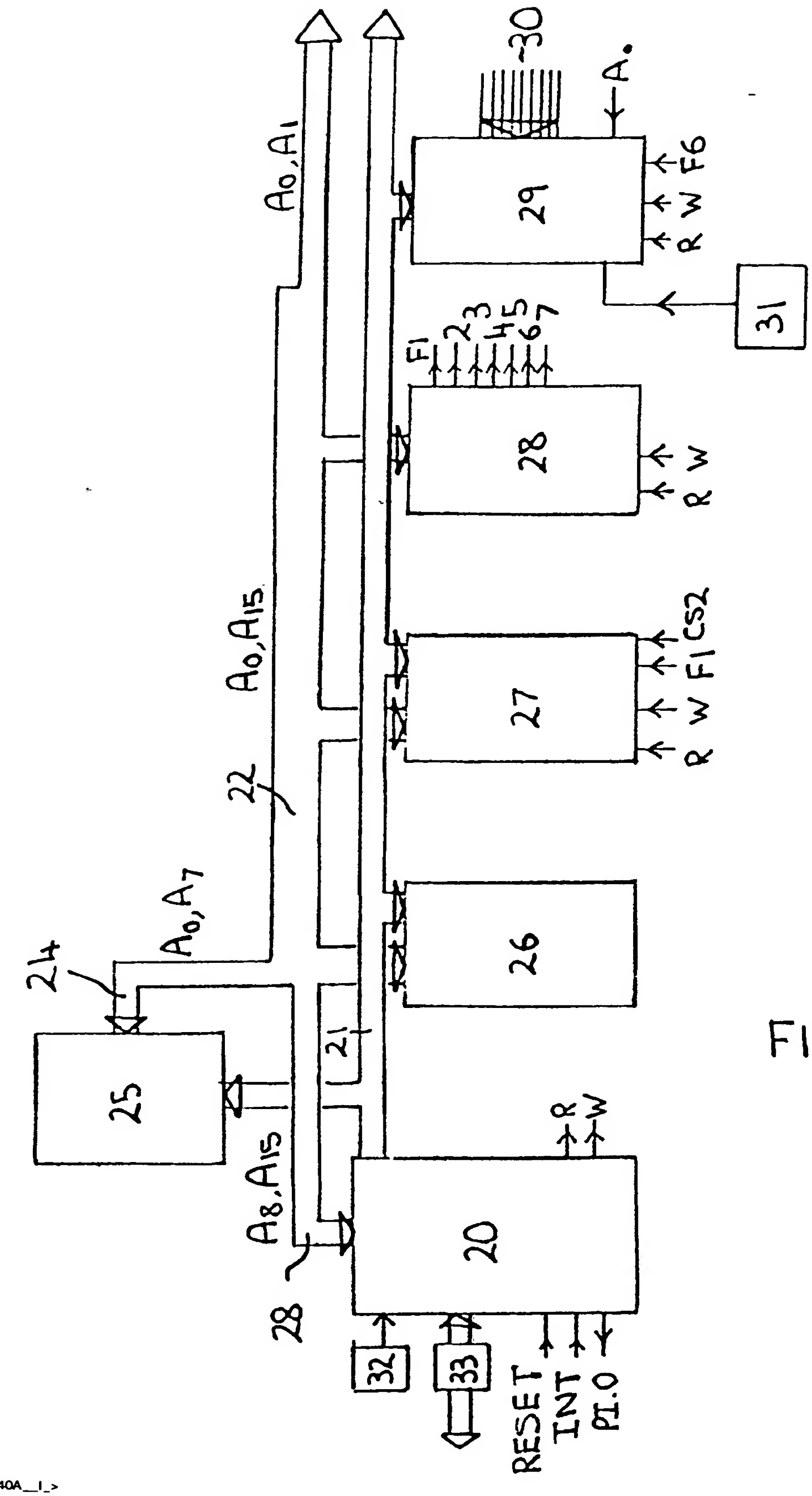

20
21
22
24
25
26
27
28
29
30
31
32
33
A0,A1
A0,A15
A0,A7
A8,A15
R W F6
R W
R W F1 CS2
F1 2 3 4 5 6 7
A.
R W
RESET
INT
P1.0

FIGURE 3

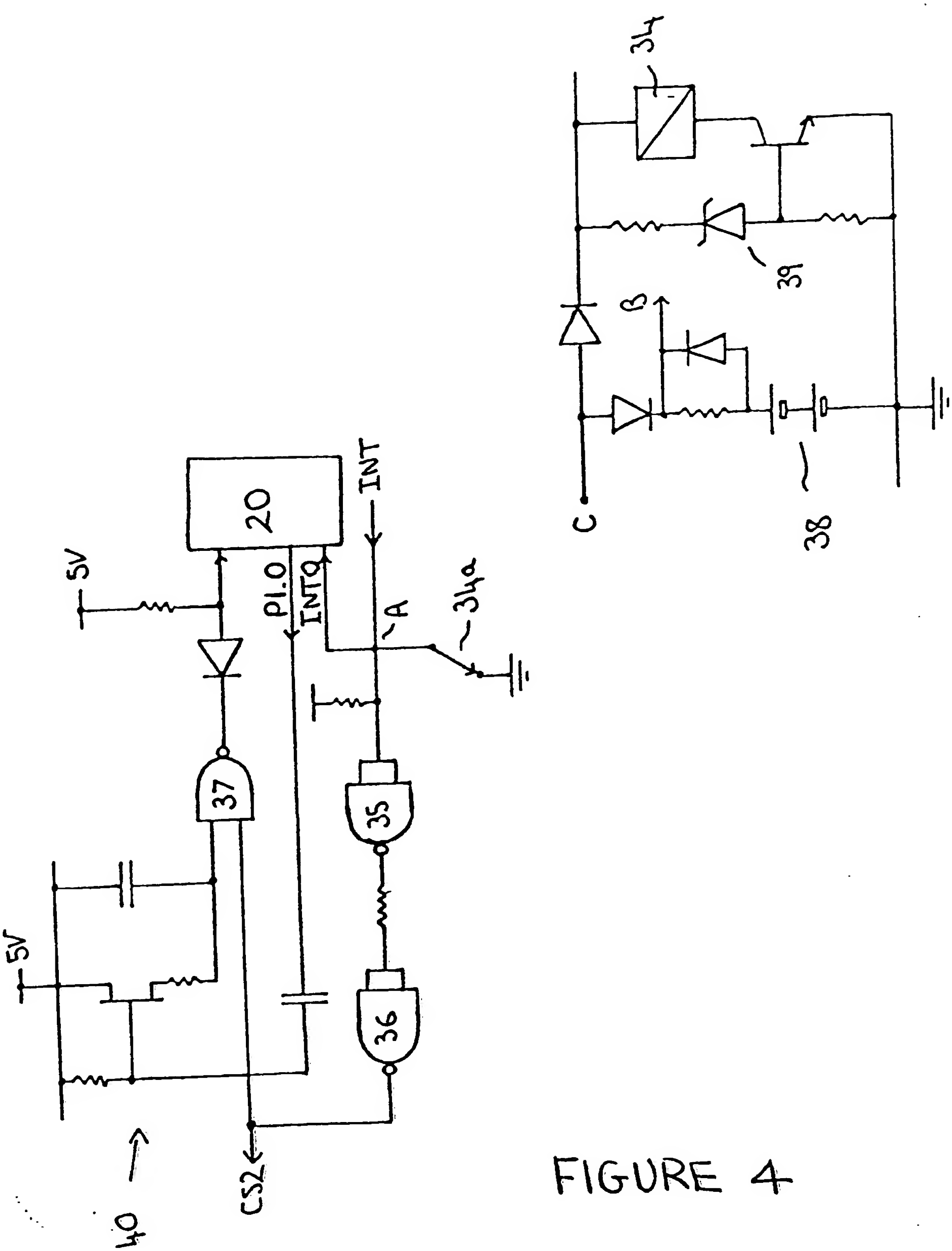
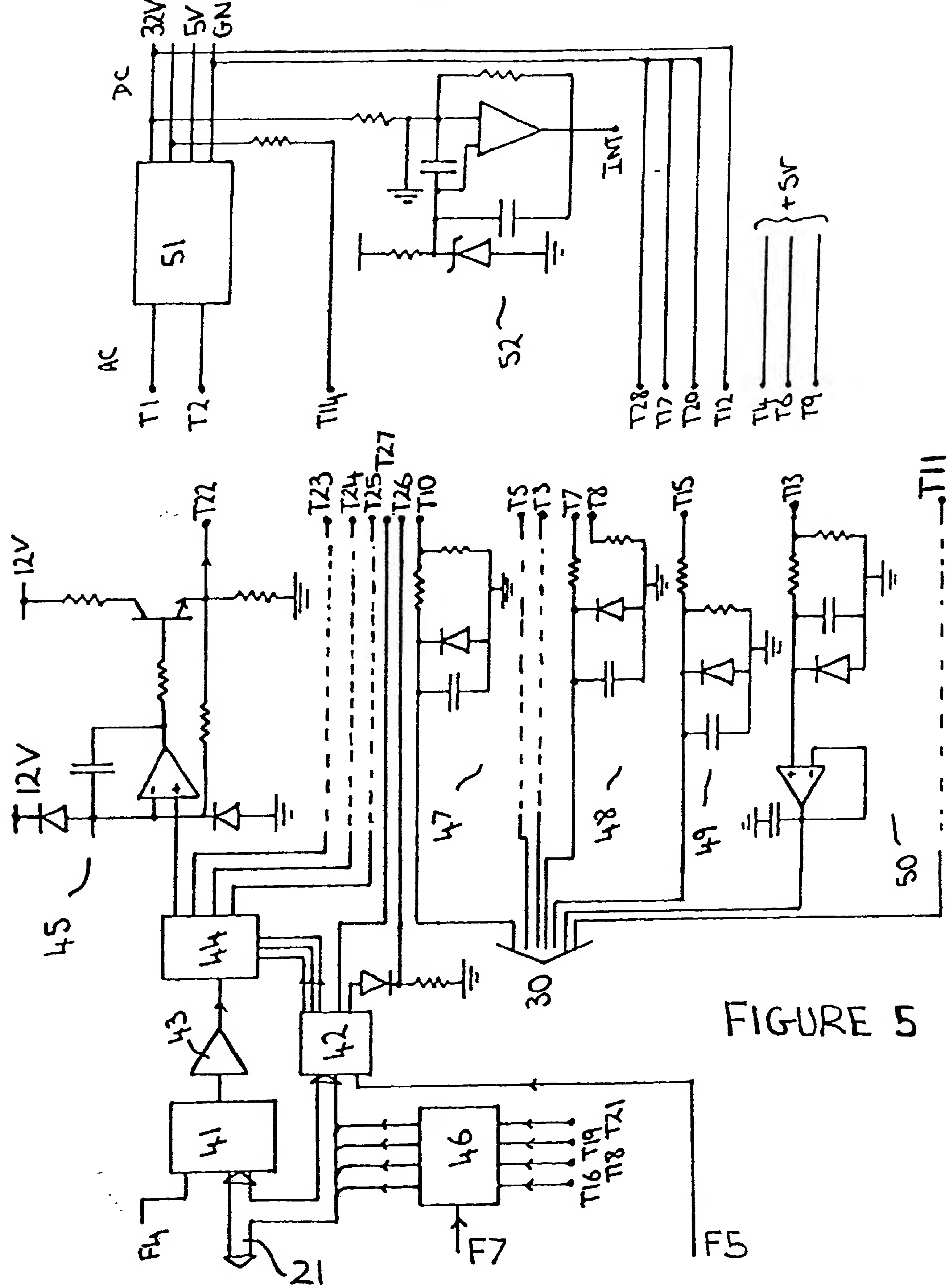


FIGURE 4



32V
12V
5V
GND
DC
AC
51
52
INT
+5V
T1
T2
T14
T28
T17
T20
T12
T4
T6
T9
12V
12V
T22
T23
T24
T25
T27
T26
T10
T5
T3
T7
T8
T15
T13
T11
45
47
48
49
50
44
43
42
41
46
30
21
F4
F7
F5
T16
T18
T19
T21

FIGURE 5

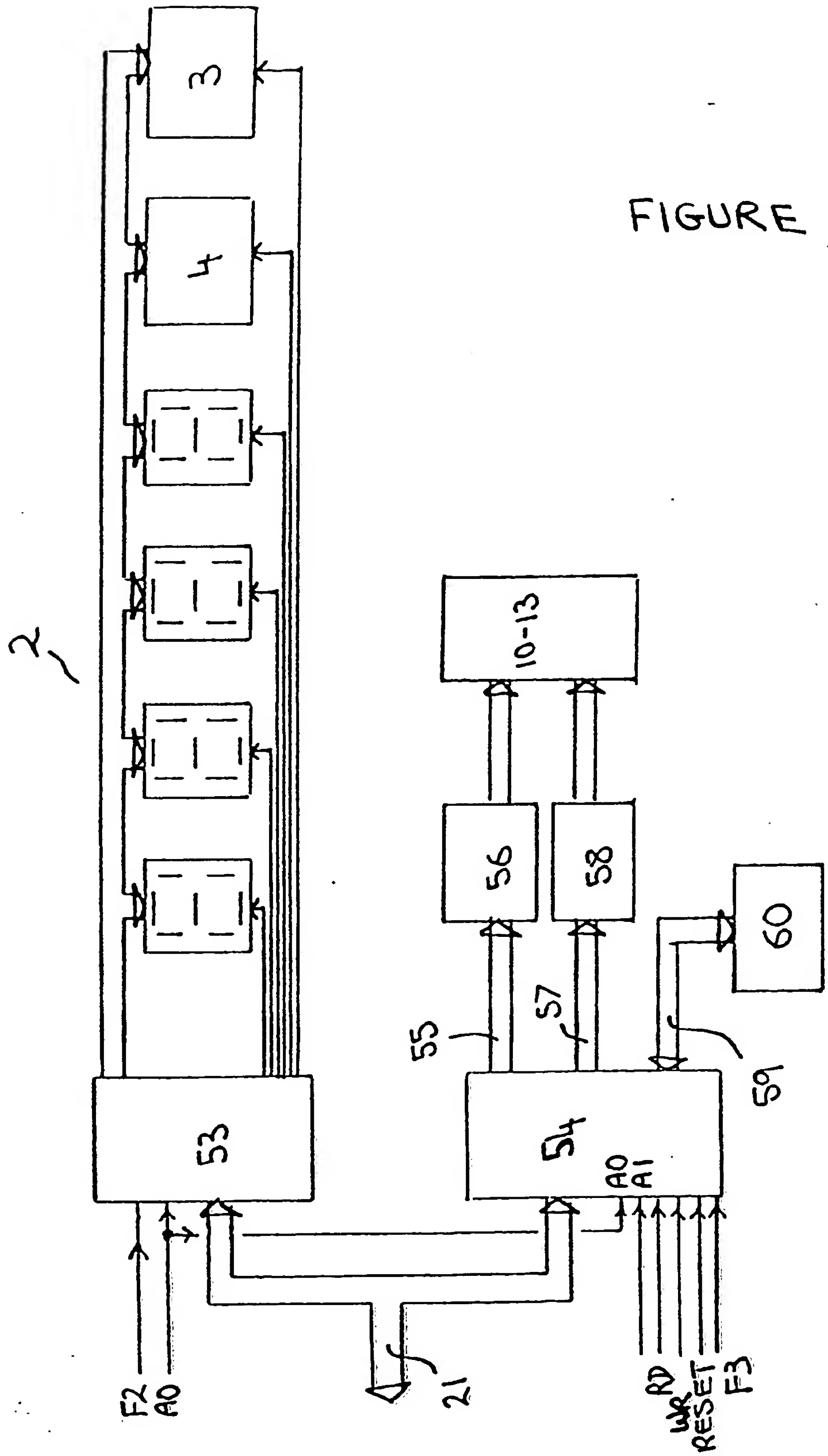


FIGURE 6

CONTROLLERS

This invention relates to controllers and is particularly applicable to controllers intended for the control of many different water and air-based heating and ventilation control schemes, such as multi-stage PID controllers.

According to one aspect of the present invention, there is provided a controller for the control of at least one control loop, the controller comprising, for the or each loop,

at least one input for receiving an external value,

at least one output for delivering a control value,

means for defining as a multiplicity of parameters of the control-loop the received external values, the control value or values and adjustable parameters of the loop, where one of said adjustable parameters defines a control set-point,

means for producing the control value or values in dependence upon received external value or values and values or states of adjustable parameters of the loop,

a first display means for displaying one at a time the value or state of each of a plurality of parameters,

selector means for selecting the parameter to be displayed at the display means,

second display means comprising discrete display elements with associated defining legends for respective displayable ones of the parameters for indicating which is the parameter currently selected, and

adjustment means operable to adjust the value or state of a currently displayed adjustable parameter.

In a preferred embodiment, the controller contains provision for defining, for the or one loop, multiple stages, each stage having its own controller output, for use in providing multi-stage control.

Preferably, the controller comprises means for the control of a second control loop, wherein the controller

may further comprise, for the second control loop, a single stage controller output.

Preferably, the controller includes means responsive to whatever may be connected to the input or inputs to determine the selection of a selected set of said parameters for use by the producing means and for display by the second display means.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a view of the front panel of a controller;

Figure 2 is a connection diagram for the controller of Figure 1;

Figure 3 is a schematic diagram of a portion of a microprocessor board of the controller of Figure 1;

Figure 4 is a schematic diagram of other elements of the microprocessor board;

Figure 5 is a schematic diagram of an input-output board of the controller of Figure 1; and

Figure 6 is a schematic diagram of a display board of the controller of Figure 1.

With reference initially to Figures 1 and 2, there is illustrated the front panel and a wiring diagram of a multi-stage PID microprocessor-based controller intended for the control of many different water and air based heating and ventilation control schemes. The controller is able to control two separate control loops, one of which is a multi-stage PID control loop and the other of which is a single-stage PID control loop primarily intended for frost-protection purposes. The controller also includes a programmable multi-slope compensator to enable the primary control loop to behave as a compensator or as a reset controller.

With particular reference to Figure 1, it will be seen that the controller 1 comprises a four digit/seven

segment LED display 2 adjacent which is an array of five LEDs 3 with accompanying legends to indicate the units if any of the value or state that is currently on display 2. To the right of the set of LEDs 3 is a set of status LEDs 4, again each LED having an associated legend to define to the user its function. Below the display 2 are four buttons, the first of which is a pass-number button 5, the second and third of which are incrementing and decrementing buttons 6 and 7, and the fourth of which is an "enter" button 8. Below items 2 to 8 is a system parameter list 9 wherein each of the multiplicity of system parameters of the controller is given an associated LED, together with a legend to define its function or meaning. This system parameter list is in four separate groups, the first group 10 being a list of non-adjustable parameters relating to the primary control loop, followed by a group 11, relating to adjustable parameters of the primary loop. Similarly, there is a non-adjustable group 12 for the secondary loop, together with an associated adjustable group of parameters 13.

Finally, the control panel of the controller has down and up parameter select buttons 14 and 15.

The above items will be discussed in more detail hereinafter.

Figure 2 is a diagram of the connections to and from the controller, these connections being labelled T1 to T28.

Terminals T1 and T2 are connected to the live and neutral respectively of a 24 volt 50 Hz supply for the controller.

Terminals T3 and T4 provide connections for an external secondary loop control sensor, e.g. a thermistor. As indicated in Figure 2, terminal T4 is supplied with 5 volts by the controller. That 5 volt supply is also provided to terminal T6 which provides with terminal T5 a connection for an external primary loop limit sensor, which again may be a thermistor.

Terminals T6 and T7 provide connections for a further external sensor, in this case a reset/outside sensor, which as with the previous sensors, may be a thermistor. In the mode as illustrated, terminals T7 and T8 are joined together but, if the link is removed, outside sensors may be shared by the use of terminals T7 and T8.

Terminals T9 and T10, with terminal T9 held at 5 volts, provide connections for the primary loop control sensor, preferably again a thermistor.

Terminals T11 to T13 provide for the connection of a humidity control sensor and a humidity limit sensor, providing between 4 and 20 ma. These may be used instead of the primary loop control sensor connected to terminals T9 and T10 and primary loop limit sensor connected to terminals T5 and T6. In other words, primary loop control can be by way of humidity rather than temperature if required. Terminals T14 and T15 provide, in conjunction with terminal T28, connections for an external potentiometer by which a remote set point can be set, i.e. the set point of the controller can be adjusted within limits by means of the potentiometer.

Terminals T16 to T21 provide four digital, voltage free, inputs, e.g. a frost input, a night input, a MFA override and a boost input.

The set of terminals T22 to T25 provide output signal connections for four controlled devices, the first three being 0 to 10 volt outputs suitable, for example, for a heater, damper control and cooling. The fourth output is again a 0 to 10 volt output for secondary loop control.

Finally, terminals T26 and T27 provide an output for an external relay, in particular for an alarm.

As is described with reference to Figures 3 to 6, the controller is composed of three circuit boards, the circuit board illustrated in Figures 3 and 4 being a microprocessor board incorporating an 80C31 microprocessor and having an 8 bit data bus 21 and a 16

bit address bus 22.

The microprocessor is indicated at 20 in Figure 3. Bits 8 to 15 of the address bus are provided directly by the microprocessor on bus 23 and bits 0 to 7 are provided on bus 24 by means of a latch 25, of type 74HC573, obtaining its data from the data bus 21. The microprocessor provides read and write signals denoted R and W which are used throughout Figures 3 to 6 where indicated to control other integrated circuits of the controller. Coupled to the address and data buses 21 and 22 is an EPROM 26 containing the controller software to be described in more detail hereinafter. Circuit 26 is of type 27C512. Working memory is provided by integrated circuit 27 of type 6264LP which is random access memory controlled by the signals R and W and also by an address signal F1 derived from an address decoder 28 connected to receive bits 8 to 15 of the address bus 22 and to produce therefrom chip select signals F1 to F7.

Also included on the microprocessor board is an analog-to-digital converter of type UP7004 and denoted 29 in Figure 3. It has 9 inputs designated 30 coupled to the input/output board to be described hereinafter. It is selected by means of chip select signal F6 from the address decoder 28.

The analog to digital converter is provided with a 1 Mhz clock from a clock generating circuit 31 and the microprocessor is provided with a 11.0592 Mhz clock signal from a clock circuit 32.

The board also includes an RS232 device driver 33 of type MAX 238 to enable serial control of the controller as required.

Also on the microprocessor board and illustrated in Figure 4 is a portion of the circuitry for detecting power up and loss of power and providing a RESET signal and an interrupt signal INT 0.

The circuit in the lower right hand corner of Figure 4 incorporates a relay 34 with relay contact 34A

arranged, when the relay is not energised, to put point A, connected to the INT 0 pin of the microprocessor, at zero potential. This zero level at point A is also transmitted by three NAND gates 35, 36 and 37 to the RESET input of the microprocessor to maintain the microprocesser RESET. This RESET signal will additionally be connected to the other boards as will be described hereinafter. This power up detect circuit additionally includes a battery backup facility by way of a rechargeable battery 38 supplying a supply voltage at point B which will be connected to maintain energisation of the microprocessor and is also connected to maintain operation of the NAND gates 35, 36 and 37. The internal power supply driving the CMOS circuits within the controller at a voltage in the range of 5.4 to 5.7 volts is connected to the power supply rail at C and, during power up when that voltage level is not reached, relay 34 will be maintained in its non-conducting condition. Once the voltage at point C increases above 4.5 volts, defined by Zener diode 39, the relay 34 operates to isolate the point A from ground, thus allowing interrupt signals to appear at point A and additionally causing the reset of the microprocessor or/and other circuits. This reset causes the software of the controller to commence its initialisation procedures which will be described hereinafter. During normal operation, the microprocessor emits pulses on its output P1.0 to the circuit generally indicated at 40 and these pulses maintain the capacitor charge sufficiently to block the NAND gate 37 to prevent any further reset of the system. If a failure occurs such that the pulses cease from the output P1.0, then the circuit 40 causes the reset to be reactivated.

If power down is detected by the power down circuit to be described hereinafter, a signal INT is produced at the point A and is supplied to the processor where that interrupt is arranged by software to continue the action of the current instruction but then to stop, entering a

loop of null operations.

Figure 5 is a schematic diagram of the input/output board of the controller. The data bus 21 passes to this board, connecting to a digital-to-analog converter 41 (type ZN589E) and an octal latch 42 (type UCN5800). Also going to this board are selected ones of the addressing signals F1 to F7, selectively to activate circuits on this board. The output of the digital to analog converter passes via a scaling amplifier 43 to a demuliplexer 44 (type C44051B) controlled by the latch 42 to sequence through the four outputs of the demultiplexer, these outputs being connected to the terminals T22 to T25 by four identical output circuits 45, only one of which is shown in this Figure.

Another output of the latch is arranged to send a digital signal to output terminals T26 and T27 intended to provide a signal for the alarm mentioned with reference to Figure 2.

The data bus 21 additionally connects to a buffer circuit 46 of type 74HC385 and having four inputs connected to the digital terminals T16, T18, T19 and T21.

There is shown connected to the analog to digital converter input 30 a variety of input circuits including three identical circuits 47 (only one of which is shown) connected to thermistor input terminals T3, T5 and T10. A similar input circuit 48 is provided but in this case it is connected to two terminals, T7 and T8, which may be linked for usage as with the circuits 47.

Terminal T15 is shown coupled to the analog to digital converter by an input circuit 49. Terminals T11 and T13 are connected to two identical input circuits 50, only one of which is shown and comprising circuitry for current to voltage conversion to accept 4 to 20 MA current data from humidity sensors.

Also included on this board is a power supply circuit 51 delivering 32, 12 and 5 volt outputs as indicated and also driving a power loss detector circuit

52 which provides the signal INT in the event of power loss.

Figure 6 is a schematic diagram of the display board of the controller. The data bus 21 is connected to an 8 bit multiplexed display driver 53 of type ICM7228C, that driver 53 additionally receiving a write signal F2 and a mode signal which is bit 0 from the address bus. This driver drives an eight segment display of four digits constituting the display 2 of Figure 1. It additionally drives two groups of LEDs, these being the status LEDs 4 and the units LEDs 3.

The data bus and bits 0 and 1 of the address bus pass to a PIA circuit 54 of type UPD71055C also receiving the chip select signal F7 and the R and W signals from the microprocessor. This PIA circuit has a first output bus 55 passing via a Darlington driver 56 of type UDN-2982A to address the rows of a matrix of LEDs constituting the LED groups 10 to 13 of Figure 1. A further output bus 57 passes by way of a Darlington driver 58 of type ULN2003 to address the columns of the matrix of LEDs.

The PIA circuit 54 additionally has six circuit inputs 59 connected to a keypad 60 having the switches 5 to 8 and 14 and 15 shown in Figure 1.

The described hardware is controlled in its function by software in EPROM and data in work areas of RAM.

That software initially is looking for power up, i.e. the completion of reset of the microprocessor. An initialisation routine is then actioned. Its function is to initialise the system and clear all dynamic variables (and static variables on a cold start). On a cold start, a parameter buffer is cleared and a table in the EPROM is loaded into RAM, that table defining each of the parameters in groups 10 to 13. Each parameter in the

table has stored its default value (if adjustable), its range (if adjustable), its units and its configuration. The units are flagged where marked by an * to indicate that relative humidity (%RH) may be used instead.

The configuration comprises one or two digits referring to flags defined as follows:

FLAG 1 = Primary loop control sensor (temp or humidity).
FLAG 2 = Primary loop limit sensor (temp or humidity).
FLAG 3 = Primary loop outside/reset sensor.
FLAG 4 = Primary loop RSP sensor.
FLAG 5 = Secondary loop control sensor.

The configuration additionally includes a marker, shown by an *, to indicate a NAND function, i.e. if all indicated flags are set, the parameter is made inaccessible.

The form of the table is as follows:

Function	Default	Range	Units	Config
Primary Loop				
Control sensor	-	-	deg.C*	1
Limit sensor	-	-	deg.C	1, 2
Outside sensor	-	-	deg.C	1, 3
R.S.V. sensor	-	-	%	1, 4
Stage 1 Output	-	-	%	1
Stage 2 Output	-	-	%	1
Stage 3 Output	-	-	%	1
Calculated Set-point	-	-	deg.C*	1, 3
Control Setpoint	20.0	-20/100	deg.C*	1, 3*
Low Limit	05.0	-20/100	deg.C	1, 2
High Limit	60.0	-20/100	deg.C	1, 2
Night	ON	ON/ OFF		1
Night Set-Back	10.0	00/35	deg.C	1
X1	05.0	-20/100	deg.C	1, 3
Y1	25.0	-20/100	deg.C*	1, 3
X2	35.0	-20/100	deg.C	1, 3
Y2	15.0	-20/100	deg.C*	1, 3
R1	-1.5	-20/20	-	1, 3
R2	-1.5	-20/20	-	1, 3
Stage 1 Proportional Band	25.0	00/50	deg.C*	1
Stage 1 Int Action Time	15.0	00/30	min.	1
Stage 1 Derivative	00.0	00/100	sec.	1
Stage 2 Proportional Band	25.0	-50/50	deg.C*	1
Stage 2 Int Action Time	15.0	00/30	min.	1
Stage 2 Derivative	00.0	00/100	sec.	1
Stage 3 Proportional Band	25.0	00/50	deg.C	1
Stage 3 Int Action Time	15.0	00/30	min.	1
Stage 3 Derivative	00.0	00/100	sec.	1
Deadzone 1-2	02.0	00/99	deg.C*	1
Deadzone 2-3	02.0	00/99	deg.C*	1
Minimum Fresh Air	30.0	00/100	%	1
Minimum Fresh Air Override	OPEN	OPEN/SHUT	-	1
Boost ON/OFF	ON	ON/OFF	-	1
Frost input ON/OFF	ON	ON/OFF	-	1
Outside Frost ON/OFF	ON	ON/OFF	-	1, 3
Outside Frost	05.0	-05/35	deg.C	1, 3
Control Frost ON/OFF	ON	ON/OFF	-	1
Control Frost	05.0	-05/35	deg.C	1
Sample Interval	10.0	01/300	sec.	1
Secondary Loop				
Secondary control sensor	-	-	deg.C	5
Stage output	-	-	%	5
Set point	10.0	-20/100	deg.C	5
Night	ON	ON/ OFF	-	5
Night Set-Back	05.0	00/35	deg.C	5
Stage Proportional Band	25.0	00/50	deg.C	5
Stage Int Action Time	15.0	00/30	min.	5
Stage Derivative	00.0	00/100	sec.	5
Boost ON/OFF	OFF	ON/OFF	-	5
Frost input ON/OFF	ON	ON/OFF	-	5
Outside Frost ON/OFF	ON	ON/OFF	-	5, 3
Outside Frost	05.0	-05/35	deg.C	5, 3
Control Frost ON/OFF	ON	ON/OFF	-	5
Control Frost	05.0	-05/35	deg.C	5
Sample Interval	01.0	01/300	sec.	5

Once that table is loaded, tests are made on the analog values appearing across the terminals corresponding to FLAG 1 to FLAG 5 to see if the values are within a given range in which case the relevant sensor is assumed to exist and its FLAG 1 to 5 is set.

FLAG 1 relates to T9, T10 or T11, 12 (mutually exclusive) and, depending on which pair tests as existing, the unit % RH or ^{o}C is selected for the table.

FLAG 2 relates to terminals T5, T6 or T12, T13.

FLAG 3 relates to terminals T6, T7.

FLAG 4 relates to terminals T14, T28.

FLAG 5 relates to terminals T3, T4.

The data in this table will be defined more specifically hereinafter.

On completing the initialisation, normal operation is commenced with display 2 showing the value or state of the first parameter in the table that has its configuration condition set. Thus, if FLAG 1 is set, the control sensor value (^{o}C or %RH) is displayed and its LED in group 10 is lit.

Normal operation involves a set of software routines which act as follows:

A key processing routine is active to determine how the display functions and to enable parameters to be set and adjusted.

Once a key-press is detected and then de-bounced a key-poller will write the key-press to a context filter. Assuming the filter determines that the key is a legal key in the context it will be passed on to a key-processor for processing. The possible actions carried out by the key-processor are as follows:

1) Increment/decrement the current parameter pointer (keys 14 and 15). The parameter pointer is incremented or decremented depending on the key-press and the parameter buffer is loaded with the corresponding parameter value for display. Note that the system will 'skip' past parameters that are

not relevant to a particular configuration, thus saving time during system programming as well as showing up any system configuration errors.

2) Increment/Decrement the value of a static parameter i.e. of groups 11 and 13 (keys 6 and 7). If the correct password has been entered and the system is therefore in view-and-alter mode, the value held in the parameter buffer will be incremented or decremented depending on the key-press. Note that all static parameters are bounded by an upper and lower limit in the table.

By entering the appropriate security code the user may gain 'security access' to the controller's programmable parameters and may alter them at will, providing the selected parameter is not read-only. The security code is entered by using the following key sequence:-

i) Press the 'Pass Number' key: the controller will prompt with 'P000'.

ii) Use either of the increment/decrement keys 6 and 7 to adjust the pass number to, say, 'P123'. These keys have an auto-repeat facility so holding the key down for more than half a second will simulate multiple key presses.

iii) Press the 'Enter' key 8. The controller will respond with 'PASS', thus signifying that the user has gained access to the 'security mode' or 'FAIL' if an incorrect passnumber has been entered when the controller will revert back to view-only mode.

iv) Once in 'security mode' parameters may be altered at will by selecting the parameter with the parameter select keys 14 and 15 and modifying it with the increment/decrement keys 6 and 7. When all the desired parameters have been altered, pressing the 'Enter' key 8 will save all changes and take the controller back into view-only mode. Therefore, if the 'Enter' key is pressed by mistake during a

programming session, it will be necessary to re-enter the pass number before programming can continue.

Note that the controller will automatically return to review-only mode and all modified parameters will be returned to their old values if, after ten minutes, no key is pressed while in programming mode.

If the controller is in view-and-alter mode and the current parameter is a sensor-in-alarm parameter (dynamic parameter), then the alarm will be cleared. Thus, if a sensor flagged by one of FLAG 1 to FLAG 5 has a value out of range, an alarm flag would be set and this process will clear the alarm flag.

The software also has an analog-processor routine. A complete cycle occurs every second. On the first cycle (the configuration cycle) the analogue-processor will sample all analogue inputs to determine which sensors are configured and which are not. Once the system is configured a system-ready flag will be set which can be read by other interactive processes.

All subsequent cycles will only sample configured sensors.

The chain of events required in the sampling of a sensor input is as follows:

1. The analogue-processor issues a start conversion command.
2. There is then performed two separate A-D conversions on the sensor. The first is a dummy run and is required to stabilise the internal multiplexer of the ADC chip 29. The results from the second run are formulated and then passed back to the analog-processor for processing.
3. The results from the A-D-process are converted to a corresponding floating point temperature, humidity or offset value and written to memory.

4. If the sensor in question is a control sensor or is the outside/reset sensor then a frost check is performed.

5. If the sensor in question goes open or short circuit for three consecutive samples then an alarm is raised, as already described.

The software also has a digital input routine for the processing of each of the four digital override inputs. A bit poller routine will poll each input and on detecting a change in state will issue a begin or end event command to primary and secondary control-override processes. Since the firmware is completely dynamic, the bit-poller will also be reading the corresponding enable/disable parameters and will be watching for a change. Therefore, if a begin event command has been issued and then the corresponding parameter value is modified to disabled, even though the input is still active an end event command will be written to the primary and secondary control-override processes.

The software for display has a main process which is the display processor. The job of the display processor is to refresh the following output devices each time it is triggered from the main scheduler of the software (every 40 msec):-

1) The four digit seven segment display plus decimal point 2. The contents of the parameter buffer are first decoded and then written to data-display process (display driver chip 52 digits 0 - 3). Not only is it possible for the display to show numeric values but, depending on the attributes of the current parameter, the display may show text.

2) The single digit eight segment status display 4. The current status of each of the two control processes is read and transferred to a status-display process (display driver chip 52, digit 4). If the system is currently in alarm then that too will be shown.

3) The single digit five segment units display 3. The units attribute of the currently selected parameter is read from the table and transferred to a units-display process (display driver chip 52, digit 5).

An L.E.D. matrix-processor refreshes the L.E.D.. matrix 9 on the front panel. The matrix is refreshed at a rate of 400 Hz since it is possible for four L.E.D.s to be on at the same time.

The software also has a data logging routine which is triggered every fifteen minutes and will collect information from all major interactive processes and stores them in a 96-deep FIFO configured in the RAM 27.

The software further contains a primary-control-loop process which performs all the tasks required to generate a three stage P.I.D. output. Dynamic parameters which are re-calculated each control cycle are written to the parameter table or buffer for display purposes.

Similarly there is a secondary-control-loop process which performs all the tasks required to generate a single stage P.I.D. output. Dynamic parameters which are re-calculated each control cycle are written to the parameter table or buffer for display purposes.
Finally, there is now described the parameters used in this embodiment.

Primary Loop

Calculated Set-Point

The calculated set-point is a view-only parameter. It is the calculated output of the three-slope compensator. The calculated setpoint parameter is used as a setpoint for the primary loop when the Outside/Reset sensor is configured.

Control Setpoint

The control setpoint parameter is used as setpoint for the primary loop when the Outside/Reset sensor is not configured.

Low Limit

If the error between the low limit parameter and the

limit sensor is greater than that between the primary sensor and set-value then the controller will be in low limit and will control to the low limit set-value (using the limit sensor as input).

High Limit

If the error between the high limit parameter and the limit sensor is less than that between the primary sensor and set-value then the controller will be in high limit and will control to high limit set-value (using the limit sensor as input).

Night

The Night parameters will determine in what mode the controller will operate at night. If the parameter is set to ON, then the heating stage will modulate and the setpoint will be equal to the daytime setpoint less the Night Setback parameter value. If set to OFF, then the heating stage (stage 1) will be off during night. Stages 2 (damper) and 3 (cooling) will both be off. Note that frost protection will operate during night.

Night Setback

At night, the setpoint for the primary control loop will be equal to the daytime setpoint less the value of the Night Setback parameter.

Compensator parameters (X1, Y1, X2, Y2, R1, R2)

The controller will be able to cater for many different compensation applications by the programming of the associated (X, Y) co-ordinates and Ratio parameters. The output from the compensator is the calculated setpoint.

Stage Proportional Band

The Proportional Band of a control stage is the error (in deg. C) over which the stage output would travel from minimum to maximum during proportional only control. For example, if a stage has a 25 degC Proportional Band, then the associated stage output will change by 4% for each 1degC change in error between the desired and actual temperature.

Note that the second stage of the primary loop can be made reverse acting (i.e. its output will decrease as more cooling is required) by programming it with a negative proportional band.

Stage Integral Action Time

The Integral action time of a control stage is the time taken for that part of the stage output, due to the proportional action only, to double in magnitude, given a constant control error. Generally, integral action is the action of a control element whose output changes at a rate which is proportional to its input signal.

Derivative term

The derivative part of a P.I.D. loop will work against any sudden change in output caused by a sudden temperature or humidity change. Derivative control is the action of a control element whose output signal is proportional to the rate at which its input signal is changing.

Dead Zone

A Dead-zone between any two stages is the change in error (in degC) allowed before control is passed between control stages.

Minimum Fresh Air (MFA)

This parameter will define the minimum output of stage 2 (damper stage). For example, a value of 30% means that the minimum output level of stage 2 will be 3 volts, and control will be passed to stage 1 once this level is reached.

Minimum Fresh Air Override

This parameter simply defines whether, during M.F.A. override, the output of stage 2 is overridden to either 0V or 10V.

Boost on/off

When this parameter is set to ON the control loop will automatically enter boost when switching from Night to Day mode. The external boost input will also be

enabled.

All modes of boost will be disabled when the Boost ON/OFF parameter is set to OFF.

Frost Parameters

Frost Input on/off

When set to ON the external frost input will be active, when OFF it will be ignored.

Outside Frost on/off

When set to ON it will be possible for the control loop to enter Frost mode depending on the value of the Outside Frost setvalue parameter and the actual outside temperature. When set to OFF this function will be disabled.

Outside Frost

When the outside temperature drops below the Outside Frost setvalue then the control loop will enter frost mode and the control stage outputs will all go to their frost settings. The control loop will remain in frost mode until the outside temperature is raised above the outside frost setpoint plus 1.5 deg C hysteresis.

Control Frost on/off

When set to ON it will be possible for the control loop to enter Frost mode depending on the value of the Control Frost setvalue parameter and the actual control temperature. When set to OFF this function will be disabled.

Control Frost

When the control temperature drops below the Control Frost setvalue then the control loop will enter frost mode and the control stage outputs will all go to their frost settings. The control loop will remain in frost mode until the control temperature is raised above the control frost setpoint plus 1.5 deg C hysteresis.

Sample Interval

The sample interval is simply the time interval between control cycles (i.e. new output values calculated). For a water based system the sample rate

would need to be short, while for a typical air conditioning application it could be tens of seconds.

Secondary Loop

Control Setpoint

The Control Setpoint is the setpoint used by the secondary control loop during control.

The other parameters indicated in groups 12 and 13 are as for the primary control loop.

Status and diagnostics

Primary Loop active stage

The parameter list on the front panel is also used to pass on status information to the user. One piece of valuable information is the current status of the primary 3-stage control loop, i.e. which stage is currently active. The active stage will be shown by the appropriate Stage Output parameter flashing at a rate of 0.5Hz with an ON ratio of 3:1.

Sensor Alarms

If any one of the attached sensors becomes open or short for more than three seconds then the controller will register an alarm by flashing the ALARM status LED and the sensor parameter at 2Hz, and setting the alarm relay driver output. Control action will not be frozen but will use the last valid reading before the fault occurred. The alarm will now remain active until either the controller is powered down or it is cleared via the keypad.

Clearing an Alarm

Before the alarm is cleared, the fault should normally be resolved, otherwise the controller will simply return to alarm mode three seconds after clearing the last one. Once resolved the alarm(s) can be cleared by the following actions:-

i) Gain Security Access.

ii) Select the sensor currently in alarm using the parameter select keys. The display will show 'Err'.

iii) Press either of the increment/decrement keys 6 and 7

will clear the alarm.

Self Test

Introduction

Self test software is intended for use in locating system faults should the controller and its associated peripheral devices fail to function as normal. The self test can also be used as an aid during the commissioning phase.

Once a system fault is discovered, the unit should be turned off and the fault rectified before testing restart. It must also be mentioned that the name "SELF TEST", might imply that the unit will automatically test its own system (controller plus various peripheral devices such as sensors, digital & analog inputs etc.,) without any interaction, but this is not true. The test relies heavily on user interaction. If there is a suspicion as to the location of the fault, then by using the 'Enter' key 8, the user will be able to skip many unnecessary tests and jump straight into the appropriate test. The 'Pass Number' key 5 is used as a means of jumping back to the preceding test.

There now follows a description of all the hardware tests performed, and a choice of the permitted user actions. The order of the tests is as in the execution of the program.

Entering Self Test

To start self-test, the controller is put into the security mode. Press down and hold the 'Pass Number' key, press the 'Enter' key, and then release both keys simultaneously. The following four tests are then carried out automatically.

Internal RAM test ('tS 0')

If the test is good, then 'PASS' is displayed for a short period, and the next test is carried out. If, on the other hand the test fails, then 'FAIL' and 'tS 1' are alternately displayed until the unit is powered down.

Seven Segment Display test ('tS 2')

All segments of the display should light up instantaneously, if not, then the display is faulty. All segments will stay on for approximately one second before the next test is carried out.

Segment display test ('tS 3')

Each and every segment of the display should light up for a short period and extinguish before the next segment is lit up. The order in which the segments are turned on is, from the left-most digit (digit 0) to the right-most digit (units), and starting from the top segment (segment a) moving clockwise through to the seventh digit (segment g). If any of the segments fails to turn on, then the test should be terminated and the problem resolved before going on any further, else the next is carried out.

The remaining tests will need user interaction.

KEYBOARD test ('Ts 4')

Press any of the six keys on the keyboard, and one of the following six messages indicating the key pressed will be displayed.

'UP' : The increment key.

'Dn' : The decrement key.

'UP P' : The bottom up arrow key (parameter select).

'PASS' : The 'Pass Number' key.

'Entr' : The 'Enter' key.

Note Up to the point where the 'Enter' key is pressed it will be possible to measure the accuracy of the on-board crystal by connecting a frequency meter to the Alarm Relay Output (T27 with a 10K resistor connected between T26 and T27). The frequency meter reading should be 400 Hz q± 1Hz.

To exit the test, all keys must have been pressed at least once, and any key pressed for a second time.

Parameter/Status LED test ('tS 5')

The following five keys are allowed and acknowledged. The effect of operating them are also

described below:-

Bottom down arrow key: This key is used to light up each LED and status flag. Successive operation of the key will extinguish the previous led and turn on the next led, working downwards through the array towards the last status flag.

Bottom up arrow key: This key is used to light up each LED and status flag. Successive operation of the key will extinguish the previous led and turn on the next led, working upwards through the led array towards the first parameter led.

'Enter' key: This key is used to abandon or exit this test and begin the execution of the next test.

Analog Inputs test ('tS 6' --> 'tS 12')

There are seven possible sensors to test. These are as follows:-

(a) Primary loop control sensor : 'tS 6'.

(b) Primary loop limit sensor : 'tS 7'.

(c) Outside/Reset sensor : 'tS 8'.

(d) Primary loop RSP sensor : 'tS 9'.

(e) Secondary loop control sensor : 'tS 10'.

(f) Primary loop humidity control sensor : 'tS 11'.

(g) Primary loop humidity limit sensor : 'tS 12'.

During these tests the 'Enter' and 'Pass Number' keys are operational. Pressing the Enter' key advances to the next sensor test and pressing the 'Pass Number' key executes the previous sensor test.

Note that, unlike PID proper, the sensor display is not dynamic, the sensor is only sampled on pressing the 'Enter' key.

Digital Inputs test ('tS 13')

By shorting any one of the digital inputs to common, one of four different messages will be displayed:-

'Frst' for FROST digital input.

'Fr-A' for MINIMUM FRESH AIR input.

'Nite' for NIGHT input.

'bost' for BOOST input.

To exit this test and execute the next test, press the 'Enter' key.

Analog Outputs test ('tS 14' -> 'tS 17')

There are four analog outputs to test. These are as follows:-

(a)	Primary	Loop stage 1 output	:	'tS 14'
(b)	Primary	Loop stage 2 output	:	'tS 15'
(c)	Primary	Loop stage 3 output	:	'tS 16'
(d)	Secondary	Loop stage 1 output	:	'tS 17'

In each of the four tests pressing the increment/decrement keys will increment/decrement the associated 0-10V output in steps of approximately 40mV. Holding down the key will increment or decrement the output at a constant rate (auto-repeat facility).

Alarm Output ('tS 18')

Connect the external relay to the PID controller (pi T26 and T27). Ensure that the default condition of the relay is OFF.

Pressing the increment/decrement keys will energise/de-energise the relay coil respectively, at the same time the display will show ON/OFF. One should check that when showing ON the relay contact resistance is < 1ohm, and when showing OFF the relay contact resistance is > 10 Meg. ohm.

Watch-dog Test

After executing the crystal frequency test and pressing the 'Enter' key the display should be showing 'END'. If the watch-dog circuit 40 is functioning the controller should reset and thus revert back to PID mode.

CLAIMS

1. A controller for the control of at least one control loop, the controller comprising, for the or each loop,

at least one input for receiving an external value,

at least one output for delivering a control value,

means for defining as a multiplicity of parameters of the control-loop the received external values, the control value or values and adjustable parameters of the loop, where one of said adjustable parameters defines a control set-point,

means for producing the control value or values in dependence upon received external value or values and values or states of adjustable parameters of the loop,

a first display means for displaying one at a time the value or state of each of a plurality of parameters,

selector means for selecting the parameter to be displayed at the display means,

second display means comprising discrete display elements with associated defining legends for respective displayable ones of the parameters for indicating which is the parameter currently selected, and

adjustment means operable to adjust the value or state of a currently displayed adjustable parameter.

2. A controller according to claim 1 and comprising means responsive to whatever may be connected to the input or inputs to determine the selection of a selected set of said parameters for use by the producing means and for display by the second display means.

3. A controller according to claim 2, and comprising digital memory storing a plurality of records relating to respective ones of a plurality of said parameters, each record including data defining to which set or sets of the selectable sets the parameter pertains, the selector means being able to select only those parameters defined by the memory as belonging to a currently selected set.

4. A controller according to claim 3, wherein the records of adjustable parameters each includes a default

value and its range of values.

5. A controller according to any one of the preceding claims, wherein there is defined, for the or one loop, multiple stages, each stage having its own controller output, for use in providing multi-stage control.

6. A controller according to claim 5, wherein the producing means is operable to output values from the stages one at a time.

7. A controller according to claim 5 or 6 wherein the producing means comprises, for the or the one loop, means for defining a dead-zone between stages to provide hysteresis in changing control from stage to stage, said adjustable parameters including at least one value for the dead zone.

8. A controller according to claim 5, 6 or 7, the stage controller outputs comprising a heater output, a damper output and a cooler output.

9. A controller according to claim 8, wherein the producing means comprises means for defining, as one of said adjustable parameters, a minimum value for the damper output, whereby a minimum fresh air intake is defined.

10. A controller according to claim 9, wherein the producing means is operable, upon receipt of a signal at an input, to override the defined minimum value of the damper output and to replace it in the determination of the minimum fresh air intake as either low or high, those states being the states of another one of said adjustable parameters.

11. A controller according to any one of the preceding claims wherein there are at least two inputs and the producing means comprises means operable to switch from control in dependence upon data at one input to control in dependence upon data at a second input if the error between the data at the second input and one or more limit values (being one or more of the adjustable parameters) attains a given relationship or relationships

to the error between the data at the first input and the control set-point.

12. A controller according to any one of the preceding claims wherein the producing means, for the or one loop, comprises means for defining a multi-slope compensator to enable that loop to act as a compensator or as a reset controller, said adjustable parameters including programmable parameters of the compensator.

13. A controller according to any one of the preceding claims and comprising means for the control of a second control loop.

14. A controller according to claim 13, where the producing means comprises, for the second control loop, a single-stage controller output.

15. A controller according to any one of the preceding claims, and comprising for the or each stage of the or at least one control value programmable proportional, integral and differential control and said adjustable parameters including a proportional band temperature or relative humidity, an integral action time and a derivative time.

16. A controller according to any one of the preceding claims, said producing means including means for defining, as a night set-point, said control set-point minus a night setback value, said adjustable parameters including the night setback value.

17. A controller according to claim 16, said producing means including means operable to select at nightfall, in dependence upon a night status parameter, either said night set-point or shutdown of the controller, said adjustable parameters including the night status parameter.

18. A controller according to claim 17, said producing means including means selectively operable to boost or not to boost the, or at least one, control value upon transition from said night set-point to said control set-point, said adjustable parameters including a boost

parameter for determining that selection.

19. A controller according to any one of the preceding claims, the producing means comprising means operable to enter a frost mode in dependence upon data received at an input if that data attains a given relationship to an outside frost set-point value, being one of said adjustable parameters.

20. A controller according to any one of the preceding claims, said producing means being operable to calculate the or each value at regular intervals, the duration of which is one of said adjustable parameters.

21. A controller according to any one of the preceding claims, the first display means comprising an alphanumeric display.

22. A controller according to claim 21, the first display means further comprising a plurality of discrete display elements with associated legends for indicating the units of the currently displayed parameter.

23. A controller according to any one of the preceding claims, wherein said discrete display elements and associated legends are arranged physically as a list.

24. A controller according to claim 23, wherein the controller is operated to define a first and a second control loop and wherein the displayable parameters of the first loop form a first section of the list and the displayable parameters of the second loop form a second section of the list.

25. A controller according to claim 24, wherein each section is physically divided into a first subsection containing view-only parameters and a second subsection containing adjustable parameters.

26. A controller according to claim 23, 24 or 25, wherein the selector means comprises means operable to select, in sequence, a displayable parameter listed sequentially before or after the displayable parameter currently selected.

27. A controller according to any one of the preceding

claims comprising a third display means comprising discrete display elements with associated legends for displaying the current operating status of the controller.

28. A controller substantially as hereinbefore described with reference to the accompanying drawings.

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Databases (see over)

(i) UK Patent Office

(ii) ONLINE DATABASE: WPI

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Documents considered relevant following a search in respect of claims 1-28

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X,P	GB 2240640 A (VAILLANT) - whole document	1,3,21 at least
X	GB 2181274 A (TOSHIBA) - whole document	1,3,15,21 at least
X	GB 1391276 (SHELL) - see page 2 lines 40-44, lines 75-32 and lines 107-128, page 3 lines 16-20 and lines 71-73 and page 5 lines 97-111	1,3,13, 15,22 at least
X	EP 0176383 A (TELEMECHANIQUE) - see page 3 line 17 - page 4 line 17	1,3,13,21 at least
X	US 4497038 (SIEMENS) - see Column 2 line 61 - Column 3 line 16	1,3 at least

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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